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BBC TEST CHART 57:
a new grey scale reflectance chart
for colour television cameras

No. 1970/30

Research Department, Engineering Division
THE BRITISH BROADCASTING CORPORATION

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Summary

This report discusses the design considerations and use of a new grey-scale reflectance chart for colour cameras and the construction of a prototype chart based on the new design specification is described. Specification details have been passed to a manufacturer who has developed a technique enabling the charts to be produced in quantity.

1. Introduction

In order to achieve the optimum colour fidelity in the existing colour television systems it is necessary for the colour signal source to produce equal-amplitude colour-separation signals at the different levels representing white, greys and black. In the case of a colour camera this is normally obtained by correctly exposing the camera to a neutral grey-scale produced either by a rear-illuminated transparency or a front-illuminated reflectance chart and then adjusting the relevant camera controls to give balanced red, green and blue colour-separation signals. This type of test chart or transparency is normally intended to provide additional aids to camera set-up such as enabling the transfer or gamma characteristics of the camera to be checked and the signal level corresponding to black to be set.

Test charts and transparencies of this type have been in existence for a considerable time but the much-improved performance of modern colour cameras has created a need for a new grey-scale with improved neutrality, increased contrast range and modified contrast law characteristics.

2. The scene illuminant and the white point of a colour television system

When a reflectance grey-scale is used for the camera colour-balancing procedure it is useful to consider the relationship between the scene illuminant and the white point of the colour television system. In specifying the colour analysis of a colour television system, account is taken of the chromaticities of the shadow-mask tube-phosphors on which the colour-separation pictures will be reproduced. It is theoretically possible to calculate, for one particular scene illuminant and a particular set of primary chromaticities, ideal camera analysis characteristics which give (within the colour gamut defined by the primary chromaticities) exact chromatic reproduction of the original scene. In this situation the display white-point and the scene illuminant would have the same chromaticity. In present-day practice, however, the white point of the display is set to an agreed chromaticity, Illuminant D_{6500}, and the colour camera is balanced to suit the scene illuminant, which may vary over a wide range. When the scene illuminant is not D_{6500} the chromaticities and relative luminance values reproduced by the television system will inevitably differ from those visually observed in the original scene.

Optimum colorimetry may be taken to be the case in which the colour reproduction of the scene is identical with that which would be obtained if the scene were illuminated with D_{6500}. Linear matrix techniques[1] can be used to obtain a performance which is reasonably close to this optimum.

3. The neutrality of the grey-scale and the reflectance chart background

An investigation has shown that a 4% change in the unity ratio of red, green and blue signals in a linear system can produce a noticeable colour change in a receiver display balanced at D_{6500}. As the overall gamma of current television systems tends to be higher than unity, an even smaller tolerance in this ratio is required in order to preserve a good colour balance and in particular to obtain the best reproduction of facial tones.

In order to minimise colour balance errors the reflectance grey-scale must be an excellent neutral and should if possible be placed in the scene to reflect the scene illuminant. A difficulty often found with rear-illuminated transparencies lies in achieving precisely the same illuminant as that used to light the scene to be televised.

In terms of the grey-scale neutrality it was estimated from these considerations that a uniformity of reflectance of at least ± 4% over the spectral range from 400 nm to 700 nm would be required and that the spectral characteristic should not contain any abrupt changes in the central region of this band. Although the neutrality of the background to the chart is of slightly less importance, it must nevertheless be good. The final assessment of colour balance is always made subjectively from a colour display monitor and the assessment can be made more accurately if the grey-scale and background are of equal neutrality. It is also useful if the background is neutral and of uniform reflectance so that any significant shading effects introduced by the camera can be revealed.

4. White reflectance and contrast range

In most television studios it is current practice to limit the light reflected from the bright areas in a scene to about 60% of that obtained from a perfect diffuse reflector so that, with normal camera exposure, facial tones are displayed on the receiver at subjectively acceptable luminance levels. If the maximum luminance in the scene were higher, the high overall gamma of the system would cause faces to be reproduced too darkly.

The white step of the grey-scale in the test chart should therefore have a reflectance of 60% to represent the brightest area in a scene and the camera, when fully exposed to this, should produce maximum signals. Any specular reflections subsequently encountered in a scene will be reduced to 'white' level by the action of the white clippers in the camera. In television studios, the luminance levels in the scene in excess of 60% 'white' can be to a large extent controlled but this is not always possible under outside broadcast conditions. Here the test chart is used for colour-balancing as in the studio and then, if necessary, the camera exposure is adjusted to accommodate the most important part of the scene contrast range.

The contrast ratio encountered in a studio scene can be as much as 100 : 1 and a ratio of 1000 : 1 in an outdoor scene is not uncommon. Until recent years the performances of cameras and receiver display tubes limited the overall system contrast ratio to about 20 : 1. However, a modern colour camera equipped with electronic flare-correction is capable of handling a contrast ratio approaching 100 : 1. Similarly modern colour receivers viewed under favourable ambient lighting conditions are capable of displaying a similar contrast ratio but, for the average range of studio scenes and receiver display conditions, a contrast ratio of 40 : 1 is regarded as typical.

This value was therefore considered as the smallest range over which accurate camera colour balance tracking should be achieved and was therefore adopted as a useful working contrast ratio for a reflectance grey-scale. With the white step already set at 60% this would mean that the darkest step is required to have a reflectance of 1½%.

5. Grey-scale contrast law

If the steps of the grey scale are equally spaced and arranged to run horizontally across the reflectance chart, the resultant line waveform (before gamma correction) from a camera exposed to the chart describes the contrast law of the grey scale. The steps could be made to run vertically and reference made to the field waveform but the dimensions of the grey scale would then be limited due to the aspect ratio of the system.

The most suitable contrast law for a test-card grey scale would have a gamma exponent equal to the reciprocal of that to be applied in the gamma correctors of the camera. The resultant output video waveform would then appear as a linear set of steps when the gamma correction was correct. This is a convenient waveform as the equal step intervals facilitate the operational aspect of the tracking procedure and the linear display provides a quick check of the uniform gamma correction of different cameras. If two horizontal grey scales are arranged on a uniform grey background in the top and bottom halves of the chart a distinction can be readily made between incorrect camera gamma characteristics and shading effects.

However, the gamma correctors available in the current types of colour camera are not capable of fully compensating the high gamma of modern display tubes;[3] further, the contrast range over which the correction follows a pure power law is limited from practical considerations such as the effects of noise and lag in the camera signals.

From the measurements made of the gamma characteristics of different types of camera it has been deduced that a grey scale should have a contrast law with an exponent of 2·5 near white, which reduces to a value of 2·2 in the darker greys. This then allows the camera to produce a substantially linear output waveform over a contrast range of 40 : 1. The reflectance characteristics of the proposed grey scale are given in Fig. 1, which shows the values of the different steps; nine steps provide a suitable number of signal level samples at which to check colour balance.

6. Super-black

Most colour cameras are now fitted with forms of electronic compensation for flare produced in the camera optics and tubes. This normally operates by measuring the d.c. content of the linear signal corresponding to the scene and can be adjusted to mitigate the effects of any flare in the darker areas of the picture by automatically lowering the black level. A

method of setting this compensation is to expose the camera to a small very dark area surrounded by a relatively large and bright area. The compensation is then adjusted until that part of the output waveform corresponding to the small dark area remains constant as the camera exposure is varied from normal to a low value by means of the lens iris.

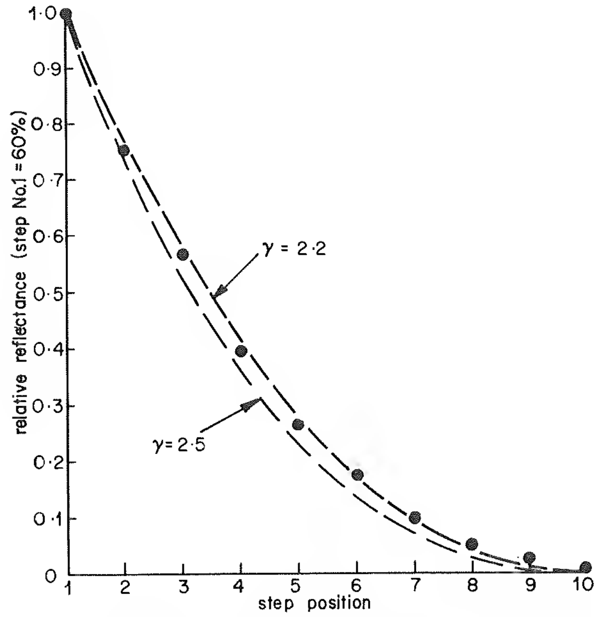

Fig. 1 • Reflectance characteristics proposed for grey-scale with equally-spaced step positions on the chart

— — — — — Gamma characteristics for comparison
● ● ● ● Step reflectances
Step position 10 corresponds to the super-black

A special 'super-black' with, if possible, zero reflectance should therefore be provided for flare correction adjustments, and may be positioned in the centre of the chart, between the two horizontal grey scales. The background should have a reflectance of about 16% so that the reflectance chart, when framed correctly by the camera and used for flare correction adjustment, simulates (with regard to brightness) an average scene. An additional advantage of a background with this reflectance is that any shading effects due to the camera and revealed by the waveform are neither exaggerated nor compressed excessively by the camera gamma correctors.

7. The use of the chart in setting black level

When using the chart for setting the camera colour balance it is necessary to establish a signal level from the gamma corrector which corresponds to black in the scene. Once set, providing flare correction is correctly adjusted, the camera should require no further adjustment of black level irrespective of the scene content, unless special effects are required.

Ideally, with gamma correctors having, say, an exponent of 0·4 it would be correct to set the level in the gamma-corrected waveform corresponding to the darkest grey step to $0{\cdot}025^{0{\cdot}4}$ (approximately 30%) of white level. This would be rather inefficient as even the maximum contrast ratio likely to be encountered in the studio, say 100 : 1, would result in a 'darkest grey' signal equal to 15% of white level. In practice it is difficult to specify the correct level. Typical gamma correctors do not conform to a pure power law in this region and tend to have unity exponents near zero. This means that, with a scene contrast ratio of 100 : 1, the waveform level corresponding to the 'super black' can be set to black level, i.e. zero level signal from the gamma correctors, with the result that the gamma-correction characteristics closely follow a pure power law over a contrast ratio of 30 : 1. Fig. 2 shows a typical colour-camera gamma-characteristic together with the step waveform obtained after gamma correction under these conditions.

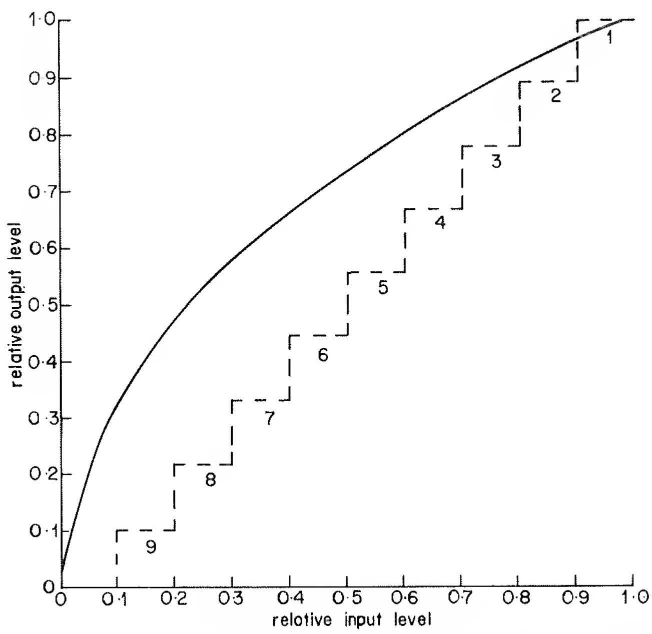

Fig. 2 • Transfer characteristics of a typical colour camera gamma corrector nominally set at $\gamma = 0{\cdot}45$

Dotted line shows calculated waveform obtained from corrector corresponding to reflectance levels of grey-scale step positions given in Fig. 1 and with super-black set to zero.

Setting black level in this manner also means that any dark-area detail in a scene with 100 : 1 contrast ratio will be transmitted so that it is possible that some receivers operating with favourable ambient lighting conditions will display this detail albeit with some distortion.

8. The prototype BBC test chart No. 57: colour camera grey scale

A prototype chart, as shown in Fig. 3, was made based upon the various considerations outlined in the

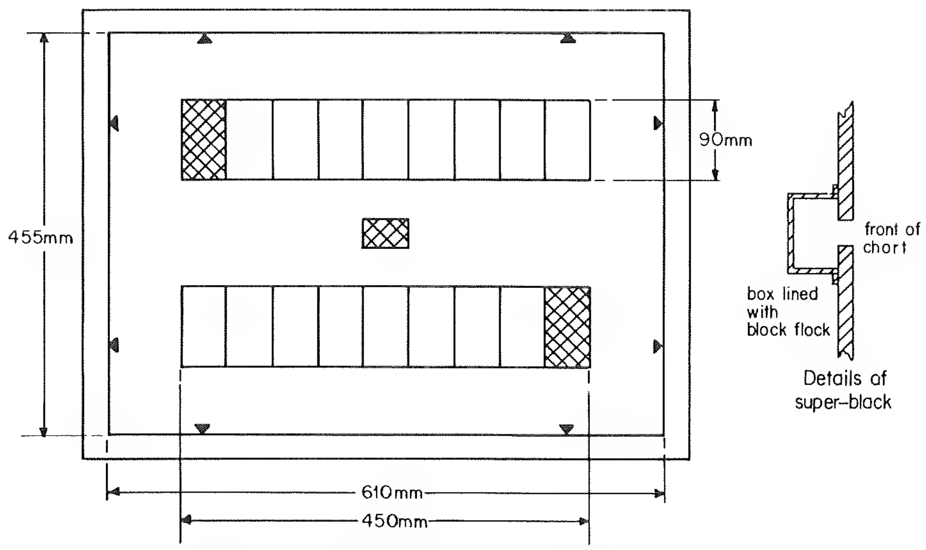

Fig. 3 • BBC Test Chart 57 colour camera grey scale format

previous sections of this report. An exhaustive search was made for a suitable material from which to make the reflectance grey-scales and after many spectrophotometric tests it was found that one special type of photographic printing paper was suitable. After suitable processing it can have excellent neutrality with a uniform reflectance within ± 4% over the required spectral band (400 nm to 700 nm). Many materials were rejected because they gave specular reflections, although they were sufficiently neutral; others were not available with an adequate number of reflectance values.

The grey-scale steps with the required reflectances specified in Table 1 were produced from the printing paper by a carefully-controlled exposure and development process. This was followed by rigorous measurement and selection to obtain the correct values and uniformity of reflection density over each step area. The contrast range required for the grey scale however extended beyond the range of the photographic material so that the low-reflectance step 9 was made from a different material having a suitably neutral matt ink-printed surface. Photographic paper was not used for the chart background as it was difficult to obtain a sufficiently small variation in the reflectance over the relatively large area required. Again, an ink-printed paper was used.

TABLE 1

Nominal Reflectance Values for Test Chart 57 Grey Scale

Step	Nominal Reflection Densities	Nominal % Reflectance Relative to Magnesium Carbonate	Nominal % Reflectance Relative to Step 1
1	0·22	60	100
2	0·35	45·7	76·4
3	0·47	34	56·6
4	0·62	24	40
5	0·8	15·8	26·4
6	1·00	10	16·7
7	1·16	6·9	11·5
8	1·51	3·1	5·2
9	1·82	1·5	2·5
'Super-black'	2·22	0·6	1·0·

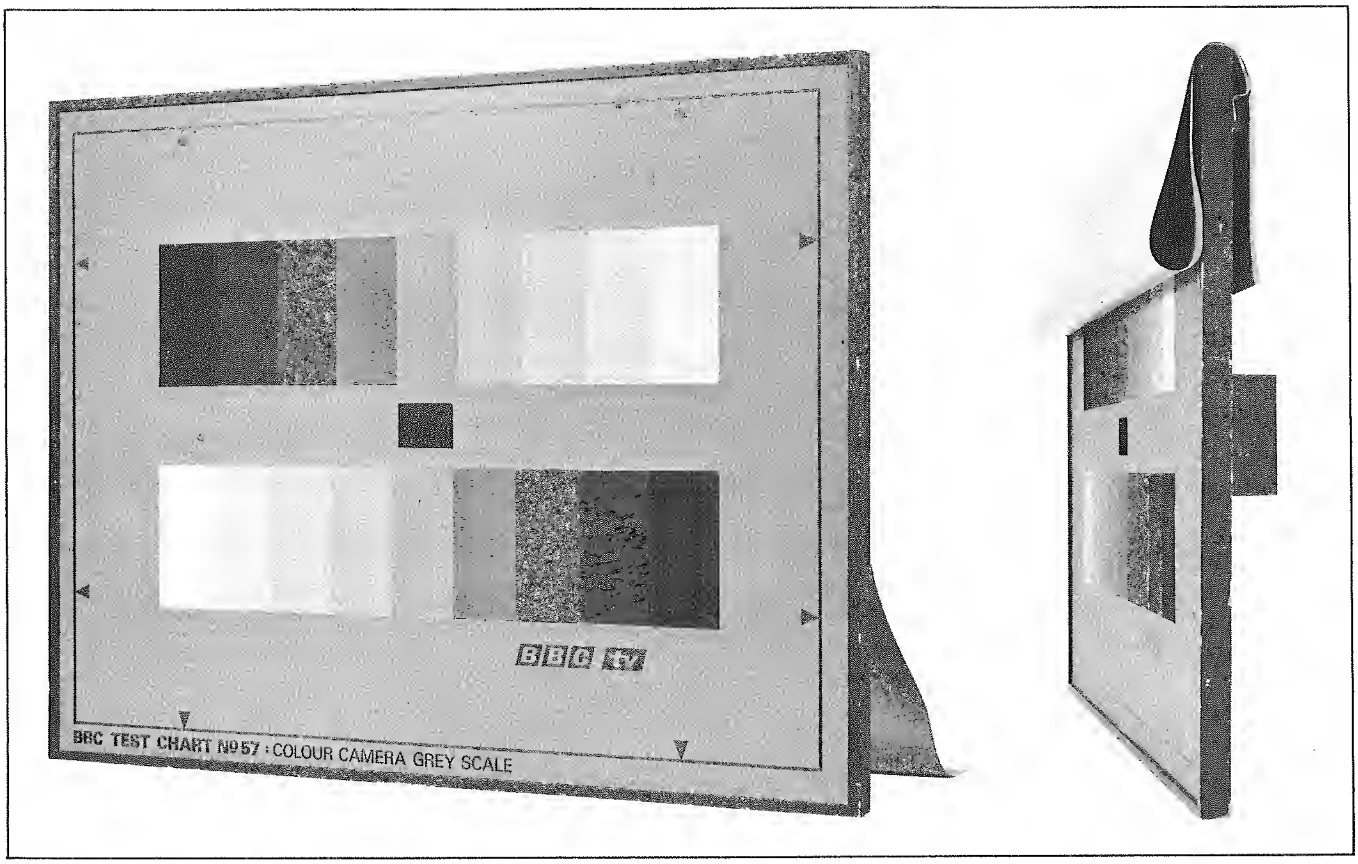

Fig. 4 - Production version of Test Chart No. 57

The 'super-black' was made in the form of an aperture forming the entrance to a small box lined with flock-paper, a type of black paper with a surface consisting of short black fibres. This arrangement reduced the amount of light reflected back out of the aperture to a minimum and produced an effective reflectance of about 0·6%, providing a 100:1 contrast ratio with the white step of each grey scale.

9. Quantity production of the test chart

A number of copies were made of the prototype and tested successfully in operational use at Television Centre over a period of about six months. Discussions were then held with a firm of precision printers with regard to development for quantity production under license. This created a number of technical problems, particularly in respect of maintaining neutrality and reflectance levels accurately. However these problems were overcome and a reasonably economic process which met the requirements was developed, involving both photographic and printing techniques; a photograph of a production version of Test Chart No. 57 is shown in Fig. 4. A considerable number of these charts have now been manufactured and are already used by many broadcasting authorities both in this country and abroad.

10. Conclusions

A new grey-scale reflectance chart has been designed which successfully meets the requirements for accurately colour balancing modern colour television cameras.

The quantity production of the charts for use by broadcasters has been achieved by a manufacturer using specially developed techniques.

11. References

1. JONES, A.H. 1967. Optimum color analysis characteristics and matrices for color television cameras with three receptors. *J. Soc. Motion Pict. Telev. Engrs*, 1968, **77**, 2, pp. 108-115.
2. The contrast law of shadow mask tubes. BBC Research Department Report No. 1969/30.

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